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HISTORICAL REVIEW OF
COST PERFORMANCE INDEX STABILITY

by

Robby J. Mitchell

June 2007

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The range method and the narrowing interval method were used to test for CPI_{cum} stability at the 50% complete point. For the range method, stability was declared if the range, which is the maximum CPI_{cum} value minus the minimum CPI_{cum} value over a specified interval, was less than or equal to .20. The results for the range method indicated that the CPI_{cum} was stable at the 50% complete point. Further analysis showed that the CPI_{cum} was stable as early as the 10% to 20% complete point. For the narrowing interval method, stability was declared when the variance of the CPI_{cum} is less than or equal to plus or minus .10 over a specified percent complete interval. The results for this method indicated that the CPI_{cum} could only be declared stable from the 50% complete point.

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HISTORICAL REVIEW OF COST PERFORMANCE INDEX STABILITY

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ABSTRACT

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The range method and the narrowing interval method were used to test for CPI_{cum} stability at the 50% complete point. For the range method, stability was declared if the range, which is the maximum CPI_{cum} value minus the minimum CPI_{cum} value over a specified interval, was less than or equal to .20. The results for the range method indicated that the CPI_{cum} was stable at the 50% complete point. Further analysis showed that the CPI_{cum} was stable as early as the 10% to 20% complete point. For the narrowing interval method, stability was declared when the variance of the CPI_{cum} is less than or equal to plus or minus .10 over a specified percent complete interval. The results for this method indicated that the CPI_{cum} could only be declared stable from the 50% complete point.

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EXECUTIVE SUMMARY

The focus of this study is to determine when the cumulative Cost Performance Index (CPI_{cum}) stabilizes for different contract characteristics. The CPI is the relationship between the budgeted costs for work performed divided by the actual costs of work performed. Once the CPI_{cum} stabilizes, program managers and analyst are able to use this index as a predictor in estimating the final cost of the contract.

Various methods were used in this study. The range method was first used to determine if the CPI_{cum} stabilized by the 50% complete point. For the range method, stability was declared if the range, which is the maximum CPI_{cum} value minus the minimum CPI_{cum} value over a specified interval, was less than or equal to .20. The results for the range method indicated that the CPI_{cum} was stable at the 50% complete point. Further analysis showed that the CPI_{cum} was stable as early as the 10% to 20% complete point.

Next the method of least squares was used to determine trends in cost performance. The results of this method showed that 67% of the contracts included in this study had a negative slope, meaning the cost performance worsened as the contract progressed.

For the narrowing interval method, stability was declared when the variance of the CPI_{cum} is less than or equal to plus or minus .10 over a specified percent complete interval. This method is more stringent than the range method as it ensures all CPI_{cum} values over the interval specified are within the plus or minus .10 variance of every

other value within the interval. The results for this method indicated that the CPI_{cum} could only be declared stable from the 50% complete point.

The categorical evaluation examined the relationship between the CPI_{cum} stabilization points and different contract characteristics. This examination allowed comparisons to be made among the various types, phases, time-frame, and baseline stability of a contract. The results showed that fixed price contracts stabilized earlier than incentive and award fee contracts. For the different phases, contracts in the production phase stabilized earlier than contracts in the LRIP and development phases. Contracts which began after the A12 program cancellation stabilized sooner than contracts which started before cancellation of the program. Lastly, contracts with stable baselines stabilized before contracts with unstable baselines.

The results of this study provide program managers and analysts with a solid foundation of CPI_{cum} stability percentages. Knowing when the CPI_{cum} may be declared stable provides confidence in the estimated cost at completion and, if a cost overrun is projected, the likelihood that a contractor can recover.

I. INTRODUCTION

A. GENERAL ISSUE

Cost estimation of Department of Defense (DoD) weapon systems is an enormous yet vitally important undertaking. With the cost of major weapon systems skyrocketing and more and more systems fighting annually for a piece of the budget, the DoD needs to ensure it is spending its money wisely. The DoD uses the Earned Value Management System (EVMS) as one management tool to accomplish this task. By tracking specific metrics derived from a contractor's EVMS, the DoD is able to gauge the value it is getting for the money it is spending. One of these metrics is the Cost Performance Index (CPI). CPI is simply the relationship between the budgeted costs for work performed divided by the actual costs of work performed. Many experts within the acquisitions community declare that this is the most critical metric provided by Earned Value Management (EVM).

However, a single CPI value provides only a snapshot in time of how a contract is performing. The true benefit comes from tracking the cumulative CPI (CPI_{cum}) as a contract progresses from start to finish. By tracking the CPI_{cum}, cost performance trends are easily recognized. Early detection of downward cost performance trends alerts management that changes need to be made quickly if the contract is to be completed within the budgeted amount.

In order to get the most value from the CPI_{cum}, we must first be able to declare that it is stable. The CPI_{cum} is declared stable when the variance over a specified interval

is less than plus or minus .10. Once the CPI_{cum} is declared stable, analysts are able to produce fairly accurate estimates for the final cost of the contract. Unfortunately, no one can be 100% certain that a contract is stable until it is completed, at which point the final cost is definitely known. Many experts have devised their own heuristics to determine when CPI_{cum} stability occurs. One method used is to declare the CPI_{cum} stable six months after the contract is awarded. Another method is to declare stability after the contract is 20-25% completed. Whether a time elapsed or percent complete method is used is usually based on the analysts' specialty and years of experience.

Although the experts have different opinions on when CPI_{cum} stability occurs, there is agreement on the benefits of a stable CPI_{cum}. As previously stated, a stable CPI_{cum} provides confidence in the estimate of the final cost. It provides early warning of potential cost overruns.

> No longer must management wait until all the funds have been spent to determine that additional budget will be needed in order to complete the full scope of a given project. The CPI thus represents the project manager's "early warning signal" and is perhaps the most compelling reason why any project should employ some form of Earned Value. (Fleming & Koppelman, 2005)

Other benefits include the ability to evaluate the contractor's internal management system and planning process.

The benefits of knowing when the CPI_{cum} is stable are the "why" of this study. The "what" is to conduct an empirical study, whose results will provide program managers with a tool in declaring when the CPI_{cum} is stable.

B. RESEARCH PROBLEM

The problem for this study is to determine when the CPI_{cum} stabilizes for contracts of different categories. The four categories to be examined are type, phase, stability, and year. These different categories will be explained in greater detail later in this chapter.

C. HYPOTHESIS

The null hypothesis is that stability occurs when a program is greater than 50% complete. Two different methods will be used to examine stability. The two methods are the range method and the narrowing interval method for which stability will be defined differently for each method. The two methods and two definitions for stability will be discussed in Chapter III.

D. SCOPE OF RESEARCH

All data for this thesis came from the Defense Acquisition Management Information Retrieval (DAMIR) system which is provided and maintained by the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (OUSD (AT&L)). The database contains cost and schedule performance for Major Defense Acquisition Programs (MDAP) dating back to 1971. The information stored in the database originates from Defense Acquisition Executive Summaries (DAES). The DAES are quarterly reports sent to OUSD (AT&L) by Program Managers (PM) for analysis and storage. These PMs represent each of the branches of the military. The actual DAES report is prepared by the PM from information provided by the contractor. The contractor

prepares a monthly report called the Cost Performance Report (CPR) containing the current month's program cost and schedule performance. The information available spans a diverse set of programs from ships, planes, and tanks, to radios, software, and support equipment. The contracts also represent programs from the various lifecycle cost and milestone phases, such as, Development (DEV), Demonstration/Validation (DEM/VAL) and Construction. They also include Low Rate Initial Production (LRIP) and Full Rate Production (FRP) and the different types of contracts currently being awarded. The list includes Firm Fixed Price (FFP), Fixed Price Incentive Fee (FPIF), Cost Plus Incentive Fee (CPIF), Cost Plus Award Fee (CPAF), and Cost Plus Fixed Fee (CPFF).

E. ASSUMPTIONS AND LIMITATIONS

The major assumption made in this thesis is that the data drawn from DAMIR is accurate. By DoD's requirement for contractors to comply with EVMS criteria, it is reasonable to expect that the data provided is reliable. Contractors of MDAP are required to be EVMS criteria-compliant.

The first major limitation is that not all contracts contain the necessary data to be analyzed. To conduct the necessary analysis, we required that a contract must have data from the 20 through 85 percent interval of completion. For many of the contracts included in the database, the full interval is not reported. Some only include data starting from beyond the 20 percent completion point while others do not include data covering the later portion of the contract. Of significant importance is that programs which are cancelled prior to the 80 percent completion point will not

be included in this study. Many of these cancelled programs are due to poor cost and schedule performance which would almost certainly prove to be unstable beyond the 50 percent completion point.

The second limitation is that some of the contracts which span the 20 to 80 percent completion interval are missing values within this range. This limitation is overcome using interpolation to fill in the missing values.

The final limitation is that I was not granted access to the Army and Air Force data in a timely manner for their data to be included in this study. Fortunately, there were 181 contracts from the Navy which met all the requirements needed to be included in this study.

Before we can begin to analyze these 181 contracts, an understanding of some of the finer points of EVMS is required. The next chapter will provide a thorough background of the EVMS and the benefits it provides.

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II. LITERATURE REVIEW

A. BACKGROUND OF EARNED VALUE

Since the 1960s, Earned Value Management (EVM) has been used as a tool to allow program managers and decision makers to have visibility into technical, cost, and schedule progress. The implementation of an earned value management system (EVMS) is a recognized function of program management. It ensures that cost, schedule, and technical aspects of a contract are truly integrated.

The concept of earned value began over a century ago by industrial engineers in American factories. By converting "planned industry standards" into "earned standards" and then relating them against "actual hours," these engineers began to focus on true cost performance (Fleming & Koppelman, 1994). In comparing actual hours against earned standards, these early industrial engineers defined what today is termed "cost variance." The approach just described is the foundation of EVM.

The earliest system within the DoD recognized as using the earned value concept was the Program Evaluation and Review Technique (PERT). PERT was developed in 1958 by the U.S. Navy as a network-scheduling device. The PERT approach attempted to simulate the development planning of a new project in the form of a logic flow diagram, and then to assess the statistical probability of actually achieving the plan (Fleming & Koppelman, 2005). Due to a combination of insufficient computer resources, complexity, and rigorous

implementation requirements, PERT was essentially abandoned as a management tool by the mid-1960s (Fleming & Koppelman, 1996).

About the time the Navy’s PERT concept faded from the spotlight, the Air Force appeared with its own version of earned value. Within the group of developers of this new approach were some of the very same people who designed the PERT approach. With PERT’s misgivings still fresh in their minds, they quickly agreed that they would not impose any specific “management control system” on private industry (Fleming & Koppelman, 2005). This new approach set 35 criteria which established the minimum requirements of an acceptable project management system. In abiding by these 35 criteria, industry simply needed to respond to basic questions based on sound project management principles. Rather than directing industry on how to manage, these criteria ensured industry used effective and measurable management practices. The first use of these criteria was in 1963, for the U.S. Air Force’s Minutemen Program (Abba, 1997). Contractors were receptive of this new approach as they were given flexibility to tailor their individual management systems in order to meet contract requirements.

In 1967, the Department of Defense, realizing the usefulness of an EVMS, published DoD instruction 7000.2 establishing the Cost/Schedule Control Systems Criteria (C/SCSC). Similar to the Air Force’s system, C/SCSC was a set of criteria that a contractor’s internal management must meet. Thus, C/SCSC was not a management system, but a guide of the minimum standards required. Although C/SCSC reigned for the next 30 years as the DoD’s standard for contract

management, it was never fully embraced by private industry. The major reasons for its lack of acceptance were excessive checklists and paperwork, specialist acronyms, and rising administrative costs due to over-implementation of the criteria (Antvik, 1998). Some viewed the earned value methodology as excessive “bean counting” (Abba, 1997). With private industries’ obvious disdain for the current system, earned value was ready for reform.

Reform came about in the mid-1990s as part of a National Defense Industrial Association (NDIA) initiative, in which private industry took a proactive role in redeveloping the minimum criteria required. The initiative consisted of modifying the original 35 C/SCSC criteria into 32 straightforward guidelines (Fleming & Koppelman, 2005). In 1997, these 32 revised criteria were published as part of DoD Instruction 5000.2R. The most significant difference between this system and its predecessors was the “buy-in” by private industry. In effect, ownership of earned value was transferred from DoD to private industry. Another significant distinction was that this system was viewed as a project management tool as opposed to a financial management one. Shortly after the publication of DoD Instruction 5000.2R, the EVMS was adopted by the NDIA as the American National Standards Institute (ANSI/EIA) Standard #748, in June 1998.

B. EARNED VALUE DEFINED

> Earned value management is a project control process based on a structured approach to planning, cost collection and performance measurement. It facilitates the integration of project scope, time and cost objectives, and the

establishment of a baseline plan for performance measurement. (Association for Project Management, 2006)

The three essential features of EVM are (1) a project plan that identifies the work to be accomplished, (2) a valuation of planned work, and (3) pre-defined metrics to quantify the accomplishment of work.

C. EVALUATION OF A CONTRACTOR'S EARNED VALUE MANAGEMENT SYSTEM

DoD Directive 5000.4 charges the Cost Analysis Improvement Group (CAIG) with developing an independent cost estimate for Acquisition Category ID programs, pre-Major Defense Acquisition Program projects approaching formal program initiation as a likely Acquisition Category ID program, and Acquisition Category IC programs when requested by the Under Secretary of Defense, AT&L. CAIG evaluates the EVMS used by the contractor to ensure efficient and accurate implementation. A technique which CAIG uses in its evaluation process is to review the contractor's Cost Performance Reports (CPRs).

D. CPR ANALYSIS

The CPR provides the status of progress of the contract. The key data elements provided in the CPR are:

- Actual Cost of Work Performed (ACWP) – The costs actually incurred and recorded in accomplishing the work performed within a given time period.
- Budget At Completion (BAC) – The Contract Budget Base less Management Reserve.
- Budgeted Cost for Work Performed (BCWP) – The sum of the budgets for completed work packages and completed portions of open work packages, plus the

applicable portion of the budgets for level of effort and apportioned effort.

- Budgeted Cost for Work Scheduled (BCWS) – The sum of the budgets for all work packages, planning packages, etc., scheduled to be accomplished (including in-process work packages), plus the amount of level of effort and apportioned effort scheduled to be accomplished within a given time period.
- Contract Budget Base (CBB) – The negotiated contract cost plus the estimated cost of authorized unpriced work.
- Estimate At Completion (EAC) – Actual direct costs, plus indirect costs allocable to the contract, plus the estimate of costs (direct and indirect) for authorized work remaining.
- Management Reserve (MR) – An amount of the total allocated budget withheld for management control purposes rather than designated for the accomplishment of a specific task or set of tasks.

From these basic data elements, performance metrics are deduced. There are many metrics which can be deduced from the data provided in the CPR; however, the only metric required for this study is the Cost Performance Index (CPI). Two other metrics are the Schedule Performance Index (SPI) and the To Complete Performance Index (TCPI). These two metrics are mentioned only to provide information on how they are used with the CPI.

The SPI indicates the ability of the contractor to control the project schedule. The SPI compares the budget for those tasks scheduled to be accomplished as of the status date with the budget for the work that was actually accomplished as of that date (Fleming & Koppelman, 1996).

The formula for computing the SPI is:

$$SPI = BCWP / BCWS \tag{1}$$

SPI can be non-cumulative or cumulative based on the data used. For illustrative purposes, assume that through the sixth month of a contract, BCWP = $95,000 and BCWS = $100,000, then the cumulative SPI = BCWP/BCWS = 0.95. The take-away is that only 95 percent of the work scheduled was accomplished, thus the contractor is slightly behind schedule (5%). An index of 1.0 means the contract is progressing exactly as planned from a scheduling point of view. If the index is greater than 1.0, the contract is progressing ahead of schedule. If the SPI varies too much from the 1.0 baseline, further investigation would be required to determine the cause for the variance from schedule. Large variances could be caused by inclement weather for an outdoor project, or could be the result of poor planning by the contractor, a problem with manufacturing, etc.

Similar to the SPI is the CPI. Like the SPI, the CPI can be cumulative or non-cumulative. The CPI indicates the ability of the contractor to control cost, and compares the budget for those tasks that have been accomplished with the actual cost of accomplishing the tasks (Fleming & Koppelman, 1996). The formula for computing the CPI is:

$$CPI = BCWP / ACWP \qquad (2)$$

From our earlier example, assume that at the end of the sixth month our ACWP = $110,000. Our CPI would then equal $95,000 / $110,000 = .864. The takeaway here is that the contractor is only earning around 86 cents of value for every dollar spent. At this point the contractor in our example is performing behind schedule and over planned budget. An index of 1.0 means that the contract is performing as planned from a cost perspective. An index

greater than 1.0 means the contract is currently performing under the planned budget. Unfortunately, the majority of contracts are similar to the example above, in that they are generally both behind schedule and over budget.

The final index to be defined informs the project manager of how well the contractor must perform throughout the rest of the contract to finish within the planned budget. This metric is the TCPI and the formula is:

$$TCPI = (BAC - BCWP) / (BAC - ACWP) \quad (3)$$

Continuing with the example presented and a BAC = $200,000, the TCPI = 1.167. To finish within the planned budget, the contractor must perform at an overall CPI rate greater than 1.167 for the remaining portion of the contract. As the contractor has performed at a CPI below 1.0 thus far, it is unlikely that the contractor will be able to meet the planned budget.

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III. METHODOLOGY

A. THE DATA

All data used in this thesis was extracted from the Defense Acquisition Management Information Retrieval (DAMIR) system. In order for a contract to be included in this study, data for the contract needed to be reported at or below the 20 percent completion point as well as at or above the 80 percent completion point. The actual data elements retrieved throughout this interval were the CPI_{cum} values. Also captured were the program name, contract subject, program phase, contract type, year contract began, year contract ended, and stability of the baseline. These elements of information will be used to categorize contracts in order to perform comparative analysis.

One hundred eighty-one contracts from 48 different programs met the criteria for inclusion. The 48 programs are representative of the major investments made by the Navy over the last 30 plus years. Samplings of these investments include the purchases of aircraft (from the F-14 through the V-22), construction of ships, ammunition research and development, and software development. The contract types represented were Firm Fixed Price (FFP), Fixed Price Incentive Fee (FPIF), Cost Plus Incentive Fee (CPIF), Cost Plus Award Fee (CPAF), and Cost Plus Fixed Fee (CPFF). The program phases represented were Development (DEV), Demonstration/Validation (DEM/VAL), Construction, Low Rate Initial Production (LRIP), and Full Rate Production (FRP).

B. METHOD OF ANALYSIS

Three different methodologies will be used to analyze the data. The first two methods will be used to validate the results attained by Captain Scott Heise in his thesis titled, "A Review of Cost Performance Index Stability" (1991). A third, more stringent method will then be used to analyze the data. The three methods are:

1. Range Method
2. Least Squares Method
3. Narrowing Interval Method

First, all 181 contracts will be used to test the hypothesis to be stated. Then the contracts will be tested on various categories, including by type, phase, year, and stability. Finally, the contracts will be evaluated by combinations of the categories.

1. Hypothesis

For the first and third methods, the hypothesis to be tested is that the CPI_{cum} stabilizes by the 50 percent completion point. The second method to be presented will not have an associated hypothesis.

2. CPI Calculations

The CPI_{cum} was extracted directly from the DAMIR system. The formula used in computing the CPI_{cum} was:

$$CPI_{cum} = BCWP_{cum} / ACWP_{cum} \tag{4}$$

The CPI_{cum} was recorded for the following percent complete points of each contract: 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 95, and 100, if these points were available. Recall that to be included in the database for this thesis,

a contract has to begin reporting at no later than the 20 percent level and end reporting at no earlier than the 80 percent level. In instances where contracts met the requirements just stated but were missing one or more intermediate CPI_{cum} values, the CPI_{cum} values were interpolated for those points. For example, if a contract had a CPI_{cum} of .97 at the 30 percent complete point and .95 at the 50 percent complete point, the CPI_{cum} used in the analysis for the 40 percent complete point would be .96.

3. Percent Complete Calculations

Percent complete is the ratio of the amount of work accomplished to date to the amount of work planned for the total contract. Like the CPI_{cum}, percent complete was extracted directly from the DAMIR system. The formula used in DAES reporting to compute percent complete is:

$$\text{PERCENT COMPLETE} = BCWP_{cum} / (CBB - MR) \qquad (5)$$

where

CBB = Contract Budget Base

MR = Management Reserve

If you recall from Chapter II, CBB – MR = BAC. Thus, a more compact formula is:

$$\text{PERCENT COMPLETE} = BCWPcum / BAC \qquad (6)$$

where

BAC = Budget At Completion

Using these two formulas to compute percent complete does have a drawback, however, if any new effort is added to a contract, the CBB, and thus the BAC, increases. This in turn causes a decrease in the percent complete calculated.

If the amount of effort added is substantial, the percent complete may actually decline from one cost performance period to the next. Contracts exhibiting this behavior are identified as having an *unstable baseline*. Earlier in this chapter, it was mentioned that stability of the baseline was extracted from the DAMIR system. In this study, a contract baseline will be declared as unstable if either (1) the percent complete decreases between any two consecutive cost performance periods or (2) the contract undergoes an "over target baseline." Over target baseline (OTB) is defined as "a project baseline that results from the acknowledgement of an overrun, and actually incorporates the forecast overrun into the performance baseline for the remainder of the work" (Fleming & Koppelman, 2005). Similar to a contract which has new effort added, a contract which undergoes an OTB will have an increase in the CBB and BAC, and a corresponding decrease in the percent complete. A contract which undergoes an OTB will be declared as having an unstable baseline regardless of whether the percent complete actually decreases between any two consecutive cost performance periods. The reader should be cautioned not to confuse the stability of the baseline with CPI stability. Stability of the baseline is one of the categories which will be analyzed.

Another calculation which has been used to determine percent complete substitutes monthly BAC and final BAC in equation (6). In one study which used this approach, it was found that the number of contracts with stable CPIs was identical using both approaches (Payne, 1990). The drawback to this approach is that the final BAC must be known. For the majority of contracts available in the DAMIR system, the

final BAC is not reported. Thus, only the first approach to calculate percent complete will be used in this study.

4. Range Method

In his thesis, Heise considers the CPI_{cum} stable when the CPI_{cum} does not vary more than plus or minus .10 (Heise, 1991). He uses the range method to test for CPI_{cum} stability. To determine the range, the minimum CPI_{cum} is subtracted from the maximum CPI_{cum} located in the percent complete interval of interest. A contract is then considered stable if the range is less than or equal to .20. These procedures will be followed for the first method in this study. The interval of interest is between the 50 percent complete point and the final reported percent complete point. Although the 50 percent complete point is the parameter set in the hypothesis, analysis will also be conducted for the 40, 30, 20, 10, and 5 percent complete points.

5. Confidence Interval Calculations for the Range Method

The 90, 95, and 99 percent confidence intervals will be calculated for the mean of the ranges. The large-sample method for determining confidence intervals will be used. The large-sample method confidence interval is calculated using the following equation:

$$CI = \bar{x} \pm z_{\alpha/2} \cdot \frac{s}{\sqrt{n}} \qquad (7)$$

where

$\bar{x}$ = the sample mean

$z_{\alpha/2}$ = the two-tail z critical value

s = the sample standard deviation

n = the sample size

This method is appropriate when the sample size is greater than 40 as the standardized variable has approximately a standard normal distribution. Using 40 vice 30 as a rule of thumb for the Central Limit Theorem is due to the additional variability introduced by using the sample standard deviation in place of the population standard deviation (Devore, 2004). The level of confidence for the confidence interval indicates the number of times out of 100 that computed confidence intervals are expected to contain the true mean.

6. Least Squares Method

Analysis using the least squares method will be conducted to identify trends in cost performance. The first method (range method) focused on the variance of the CPI_{cum}. With the first method, instability was declared if the difference between the maximum and minimum CPI_{cum} values within the specified percent complete interval was greater than .20. By this definition, instability was declared whether the .20 breach occurred in the upward or the downward direction. The “upward direction” should be taken as the CPI_{cum} is increasing (improving) as the percent complete is increasing. It is theoretically possible that a majority or all of the breaches occurred in an upward direction (we will see that this was not the case). Taking the mean of the least squares will provide evidence as to the upward or downward trend of the CPI_{cum}. In

addition to the direction, this method will also provide the magnitude of the cost performance trend.

The method of least squares consists of finding the best-fit line to observed data points (CPI_{cum} values in this study). The best-fit line is the line that minimizes the sum of squared vertical deviations between the estimated line and the plotted values (Devore, 2004). The parameters which describe this best-fit line are the slope (S) and the intercept. It is the slope which indicates the magnitude and direction of the line, and thus provides us with the cost performance trend. The least squares equation used to estimate the slope is:

$$S = \frac{n\sum x_i y_i - (\sum x_i)(\sum y_i)}{n\sum x_i^2 - (\sum x_i)^2} \qquad (8)$$

where

x = the percent complete

y = the CPI_{cum} value for the period investigated

n = the number of cost performance periods investigated

The equation for the intercept is not provided as it will not be used in this study.

7. Narrowing Interval Method

The range method compares the difference between the maximum and minimum CPI_{cum} values over a specified interval against a set parameter which defines stability (.20 in this study). The narrowing interval method works backward from the last reported CPI_{cum} value re-computing a narrowing interval which is determined by subtracting .10 from the

highest value and adding .10 to the lowest value seen thus far. This backwards moving process continues until the preceding complete point falls outside of the interval just calculated. Stability is declared for all percent complete points up to but not including the point which fell outside of the interval. At all other percent complete points, the CPI_{cum} is declared unstable.

The narrowing interval method will be applied to the following fictional data to help clarify the process:

Table 1. Fictitious CPI_{cum} Data

% Complete	10	20	30	40	50	60	70	80	90	100
CPI_{cum}	1.1	1.07	1.03	.98	.97	.95	.94	.88	.89	.90

We start by computing an interval which is .10 ± the last reported CPI_{cum} value. The last reported value is .90 at the 100 percent complete point. Thus, the interval is [.80, 1.00]. The preceding CPI_{cum} value is now checked to see if it is within the interval. For this example, the 90 percent complete point has a CPI_{cum} value of .89 which is within the interval. A new interval is calculated by subtracting .10 from the maximum CPI_{cum} and adding .10 to the minimum CPI_{cum} values seen thus far. The new interval is .90 - .10 to .89 + .10 or [.80, .99]. The preceding CPI_{cum} value is checked to see if it is within this new interval. For this example, the preceding CPI_{cum} value is within the calculated interval until the 40 percent complete point is reached. The calculated interval at the 40 percent complete point is .98 - .10 to .88 + .10 or [.88, .98]. Now, the

CPI_{cum} value of the preceding complete point is 1.03, which falls outside of the calculated interval. Thus, the CPI_{cum} in this example would be declared stable for all complete points from 40 to 100 percent; and for the complete points from 10 to 30 percent, the CPI_{cum} would be declared unstable.

Each time a new interval is calculated it will either decrease in size or remain the same, hence the name of the method. Unlike the range method in which the interval is always .20, the interval shrinks each time a new maximum or minimum CPI_{cum} value is observed in the backward direction. The shrinking interval of this method makes it more stringent in declaring the CPI_{cum} stable as compared to the range method.

8. Confidence Interval Calculations for the Narrowing Interval Method

After applying the range method; 90, 95, and 99 percent confidence intervals will be calculated for the mean of the ranges. Calculating the mean of the intervals following application of the narrowing interval method would not provide any useful information. Instead, the percentage of stable contracts at each complete point will be computed and then, corresponding 90, 95, and 99 percent confidence intervals will be calculated for the determined percentage of stable contracts. The formula for computing the percentage of stable contracts is:

$$\% Stable = \frac{x}{n} \tag{9}$$

where

x = the number of stable contracts

n = the sample size

The formula for computing the appropriate confidence interval is:

$$CI = \frac{\hat{p} + \frac{z_{\alpha/2}^2}{2n} \pm z_{\alpha/2}\sqrt{\frac{\hat{p}\hat{q}}{n} + \frac{z_{\alpha/2}^2}{4n^2}}}{1 + (z_{\alpha/2}^2)/n} \qquad (10)$$

where

$\hat{p}$ = the sample fraction of stable contracts

$\hat{q}$ = 1 - $\hat{p}$

$z_{\alpha/2}$ = the two-tail z critical value

n = the sample size

Equation (10) produces a confidence interval for a population proportion (Devore, 2004).

9. Categorical Evaluation

This section describes how the different categories will be determined and evaluated. First, all methods previously described will be applied to the 181 contracts. The contracts will then be categorized by the type of the contract. Some of the contracts in the DAMIR system were listed having two types, such as, "CPIF/CPFF" or "FFP/FPIF." For categorizing in this thesis, contracts will be evaluated in one of these four groupings:

- FPIF
- CPFF
- CPIF & CPAF (this grouping includes CPIF, CPAF, and CPIF/CPAF combinations)
- FFP & FFP Combinations (this grouping includes FFP and any combination which has FFP as one of the types listed)

Of the 181 contracts, only six do not fit into these groupings. The next categorization will be executed on the

program's phase during the contract. Data will be grouped into three phases: Development, LRIP, and Production. The development grouping will be composed of contracts with the following description: Engineering and Manufacturing Development (EMD), Full-Scale Engineering Development (FSED, Systems Integration, Design Development, and Demonstration/Validation. The production grouping will include contracts with the following description: Buys, Construction, Production, and Follow-on Production.

Next, sorting will be performed based on the timeframe of the contract in reference to the A-12 program cancellation. The sample will be divided into the following three time periods:

- Pre-A12, which are those contracts completed by 31 Dec 1991.
- Transitional, which are those contracts which started prior to 31 Dec 1991 but were completed after 31 Dec 1991.
- Post-A12, which are those which started after 31 Dec 1991.

The purpose for conducting this sorting is to determine if the A12 program cancellation and the subsequent acquisition reforms improved defense cost performance (Christensen & Templin, 2002). The A12 program was cancelled in January 1991 due to excessive cost overruns and schedule slippages. Prior to the cancellation of the program, an administrative inquiry was conducted by the Navy's Chief Inquiry Officer, Chester P. Beach. The administrative inquiry was conducted to determine facts and circumstances surrounding the variance between the current status of the A12 Program and representations made to the Office of the Secretary of

Defense (OSD) (Beach, 1990). Following the cancellation of the program and based on the recommendations included in the administrative inquiry, numerous acquisition reforms were mandated. For a more in-depth look into this topic, see “EAC Evaluation Methods: Do They Still Work?” by Dr. David Christensen and Dr. Carl Templin.

The final grouping will be based on the stability of the contract’s baseline. Stability of the contract’s baseline was thoroughly discussed earlier in this chapter in the section titled, “Percent Complete Calculations.” The contracts will be grouped as either stable or unstable.

Analysis will be done on each of the individual groupings described in this section. Analysis will then be done on combinations of the groupings. The 181 contracts will eventually be divided and analyzed in 58 groups of various combinations based on the contract descriptions just discussed.

C. JUSTIFICATION OF METHODOLOGIES

The range method as previously discussed is well-suited for examining the variance of the CPI_{cum}. However, the range method has a slight flaw if stability of the CPI_{cum} is defined as being plus or minus .10 from its value at a specified percent complete point. With this definition, the plus or minus .10 range should be centered on this specified percent complete point. The range method does not anchor the range, but rather selects the most favorable .20 range for the data being analyzed. This flaw is more easily shown

by examining the fictional data presented earlier. The same data are presented here:

Table 2. Fictitious CPI_{cum} Data

% Complete	10	20	30	40	50	60	70	80	90	100
CPI_{cum}	1.1	1.07	1.03	.98	.97	.95	.94	.88	.89	.90

Using the range method to test for CPI_{cum} stability from the 20 percent complete point, the maximum CPI_{cum} is determined to be 1.07 and the minimum CPI_{cum} is determined to be .88. Subtracting .88 from 1.07 results in a range of .19 which is less than .20, thus, the CPI_{cum} is declared stable at the 20 percent complete point. However, the definition of stability for CPI_{cum} was not met. The CPI_{cum} value at the 20 percent complete point *did* vary by more than plus or minus .10 from this point, in fact, it varied by minus .19 [=1.07 - .88]. Although the range method fails if it is used to verify the definition of CPI_{cum} stability as being plus or minus .10, it succeeds if it is used to verify CPI_{cum} stability as being within a set parameter (.20 in this study) over a specified interval. The range method will be used in this study to verify stability using the latter definition just presented.

Unlike the range method which attempts to verify CPI_{cum} stability, the least squares method investigates trends of the CPI_{cum}. The mean of the slopes identifies the direction and magnitude of the average contract.

The narrowing interval method overcomes the flaw described in using the range method to verify stability of

the CPI_{cum} defined as being within plus or minus .10 of a specified percent complete point. This method ensures that the CPI_{cum} value at each percent complete point is within plus or minus .10 of the CPI_{cum} value at every other percent complete point in the interval defined. Since this method ensures all points are within the plus or minus .10 span, it is more stringent in declaring the CPI_{cum} stable, which will be seen in the next chapter.

Throughout this paper, all discussion regarding the cost performance index has referred to the CPI_{cum}. A thorough analysis of the stability of the non-cumulative CPI was conducted by Heise. In his study, Heise found that the non-cumulative CPI was far less stable than the CPI_{cum} (1991). Intuitively, cumulative CPI values should tend to stabilize sooner than the non-cumulative CPI values due to their cumulative nature. Therefore, stability of non-cumulative CPI values will not be examined in this study.

Another method – not examined in this study – is the method used by Christensen and Templin (2002). In their paper, they compared the final CPI_{cum} against the CPI_{cum} at the 20 percent complete point. If the absolute difference between the two values was greater than or equal to .10, the CPI_{cum} was declared unstable. This method only looked at the end points of the interval. Thus, it is possible that intermediate points within the interval breached the .10 threshold. As the narrowing interval method checks the .10 threshold for all points within the specified interval, this drawback is overcome.

IV. RESULTS

A. RANGE METHOD

The range method was used to validate the results achieved by Heise, and the full results are listed in Appendix B. The range value indicates the difference between the maximum and minimum CPI_{cum} values observed from a specified percent complete point to the last reported complete point. A summary of the results is provided in Table 3. The table includes the number of contracts analyzed, the number of contracts having a stable CPI_{cum} (range less than or equal to .20), the percentage of contracts having a stable CPI_{cum}, the maximum range observed, the minimum range observed, the mean of the ranges, and the standard deviation of the ranges.

Table 3. Summary of the Range Method CPI_{cum} Results

	Percent Complete					
	5%	10%	20%	30%	40%	50%
Number of Contracts	103	141	180	181	181	181
Number Stable	79	121	167	174	175	175
Percent Stable	77%	86%	93%	96%	97%	97%
Maximum Range	1.05	0.71	0.35	0.34	0.31	0.31
Minimum Range	.02	.02	0	0	0	0
Mean of the Ranges	0.172	0.132	0.104	0.088	0.075	0.063
Standard Deviation	0.164	0.097	0.066	0.058	0.053	0.052

Table 4 presents the results attained by Heise using the range method on 155 contracts taken from the Defense Acquisition Executive Summary (DAES) database. The 155

contracts represented contracts from all branches of the armed services. The results are presented in the same format as Table 3. One exception is that Heise uses the 0% complete point vice the 5% complete point as was used in this study. The 5% complete point was used in this study due to the limited number of contracts which had data reported below this point.

Table 4. Heise's Summary of the Range Method CPI_{cum} Results (Heise, 1991, p. 33)

	Percent Complete					
	0%	10%	20%	30%	40%	50%
Number of Contracts	110	152	155	155	155	155
Number Stable	59	116	134	141	150	153
Percent Stable	54%	76%	86%	91%	97%	99%
Maximum Range	1.243	0.644	0.434	0.364	0.312	0.299
Minimum Range	0.017	0.017	0.017	0.007	0.003	0.003
Mean of the Ranges	0.262	0.145	0.115	0.096	0.081	0.069
Standard Deviation	0.213	0.103	0.078	0.068	0.056	0.051

Comparing the "percent stable" and the "mean of the ranges" rows from the two tables, the results appear to be very similar for two different sets of data. There is some overlap in the data used; however, the data from contracts used in both studies account for less than 10% of the overall data. Heise concludes his study stating that the CPI_{cum} is stable at the 50% complete point and provides evidence that it stabilizes as early as the 20% complete point (Heise, 1991). The results of this study support this conclusion using the range method and defining stability when the range is less than or equal to .20.

B. CONFIDENCE INTERVAL FOR THE MEAN OF THE RANGES

The mean of the ranges was presented in the previous section. In this section, the 90%, 95%, and 99% confidence intervals for the mean of the ranges will be presented. The confidence intervals show the number of times out of 100 that the true mean is expected to be within the calculated intervals. For the 90% confidence level, it is expected that if confidence intervals were calculated for 100 random samples (mean of the ranges in this study) taken from a population, 90 of these calculated confidence intervals would contain the true mean. As the confidence level increases, so does the confidence interval.

Tables 5 through 7 show the calculated confidence intervals for the 90%, 95% and 99% confidence levels, respectively. The tables list the number of contracts analyzed, the mean of the ranges, the standard deviation of the ranges, the two-tail z critical value, and the calculated upper and lower limits.

Table 5. 90% Confidence Interval for the Mean of the Ranges

	Percent Complete					
	5%	10%	20%	30%	40%	50%
Number of Contracts	103	141	180	181	181	181
Mean of the Ranges	0.172	0.132	0.104	0.088	0.075	0.063
Standard Deviation	0.164	0.097	0.066	0.058	0.053	0.052
Z Critical Value	1.645	1.645	1.645	1.645	1.645	1.645
Upper Limit	0.198	0.145	0.112	0.095	0.081	0.069
Lower Limit	0.145	0.118	0.096	0.080	0.068	0.057

Table 6. 95% Confidence Interval for the Mean of the Ranges

	Percent Complete					
	5%	10%	20%	30%	40%	50%
Number of Contracts	103	141	180	181	181	181
Mean of the Ranges	0.172	0.132	0.104	0.088	0.075	0.063
Standard Deviation	0.164	0.097	0.066	0.058	0.053	0.052
Z Critical Value	1.960	1.960	1.960	1.960	1.960	1.960
Upper Limit	0.203	0.148	0.114	0.096	0.082	0.070
Lower Limit	0.140	0.116	0.094	0.079	0.067	0.055

Table 7. 99% Confidence Interval for the Mean of the Ranges

	Percent Complete					
	5%	10%	20%	30%	40%	50%
Number of Contracts	103	141	180	181	181	181
Mean of the Ranges	0.172	0.132	0.104	0.088	0.075	0.063
Standard Deviation	0.164	0.097	0.066	0.058	0.053	0.052
Z Critical Value	2.576	2.576	2.576	2.576	2.576	2.576
Upper Limit	0.213	0.153	0.117	0.099	0.085	0.073
Lower Limit	0.130	0.111	0.091	0.076	0.064	0.053

The confidence interval calculations for the mean of the ranges provide further evidence that the CPI_{cum} stabilizes by the 50% complete point. By looking at Table 7, the only upper limit which breaches the .20 range, which defines stability for the range method, occurs at the 5% complete point. At the 10% complete point, the upper limit of the 99% confidence interval for the mean of the ranges is .153, which is well below our limit.

The following plot of the 99% confidence interval for the mean of the ranges illustrates how the interval narrows as the contract progresses and the CPI_{cum} stabilizes. The larger intervals at the lower percent complete points are due to the high variances in the CPI_{cum} values during the early stages of a contract. The narrower intervals at the higher percent complete points show that there is less variance in the CPI_{cum} values as the contract progresses. This narrowing provides evidence that as contracts progress the CPI_{cum} values are becoming more stable.

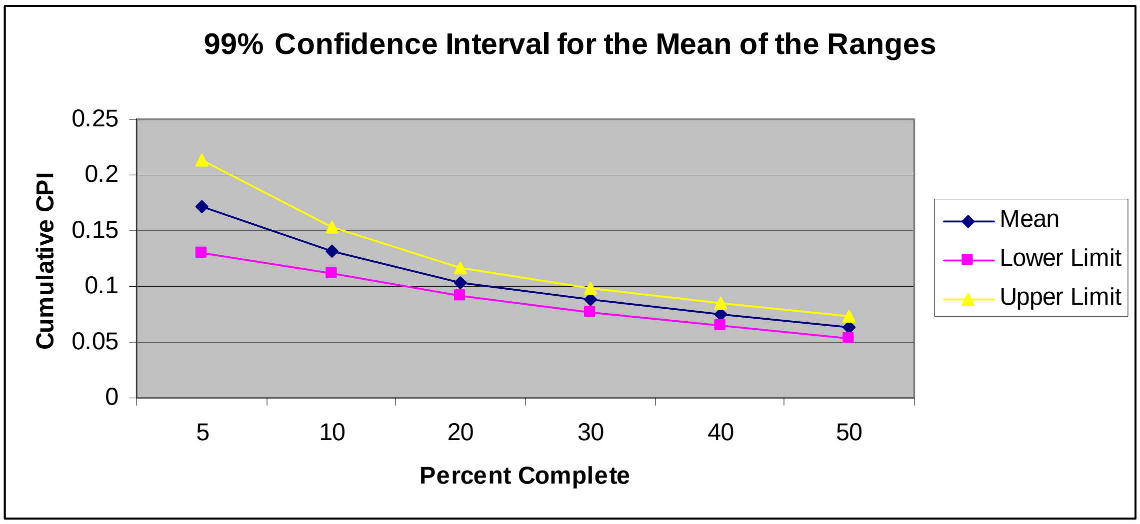

Figure 1. 99% Confidence Interval for the Mean of the Ranges

C. LEAST SQUARES METHOD

The least squares method was used to identify trends in the cost performance. The following four tables show the results of the least squares method. Table 8 presents the results from using the range method to determine stability while Table 9 presents the results from using the narrowing

interval method to determine stability. Tables 10 and 11 show the results from using the narrowing interval method on stable and unstable contracts, respectively. The column headings are the same for all tables. The first column lists the stabilization points observed. These stabilization points should be taken as the earliest complete point at which the CPI_{cum} stabilized for a given contract. The second column identifies the number of contracts which stabilized at the specified percent complete point listed in the first column. The third and fourth columns list the number of contracts which stabilized at the specified percent complete point displaying a positive or negative slope respectively. The next two columns report the maximum and minimum slopes observed, while the final column identifies the mean of the slopes. A negative mean of least squares depicts a downward trend while a positive mean of least squares depicts an upward trend. The value of the mean of least squares provides the magnitude of the slope.

Table 8. Least Squares Results for all Contracts using Range Method to Define Stability

Stabilization Point	Freq.	Total (+)	Total (-)	Slope Max.	Slope Min.	Slope Mean
70	1	0	1	-0.015	-0.015	-0.015
60	5	1	4	0.160	-0.479	-0.186
50	0	0	0	--	--	--
40	1	0	1	-0.242	-0.242	-0.242
30	7	2	5	0.336	-0.763	-0.175
20	46	13	33	0.303	-0.472	-0.073
10	42	19	23	0.259	-0.242	-0.013
5	79	25	54	0.164	-0.213	-0.026
Total	181	60	121	0.336	-0.763	-0.046

Table 9. Least Squares Results for all Contracts using Narrowing Interval Method to Define Stability

Stabilization Point	Freq.	Total (+)	Total (-)	Slope Max.	Slope Min.	Slope Mean
95	1	1	0	0.160	0.160	0.160
90	2	1	1	0.129	-0.046	0.041
80	4	0	4	-0.015	-0.479	-0.281
70	4	1	3	0.070	-0.154	-0.054
60	6	0	6	-0.050	-0.271	-0.153
50	13	5	8	0.303	-0.763	-0.106
40	15	4	11	0.336	-0.472	-0.098
30	19	4	15	0.204	-0.347	-0.107
20	40	13	27	0.206	-0.300	-0.027
10	31	12	19	0.156	-0.113	-0.006
5	46	19	27	0.105	-0.098	-0.005
Total	181	60	121	0.336	-0.763	-0.046

Table 10. Least Squares Results for Stable Contracts using Narrowing Interval Method to Define Stability

Stabilization Point	Freq.	Total (+)	Total (-)	Slope Max.	Slope Min.	Slope Mean
80	3	0	3	-0.269	-0.479	-0.369
70	2	0	2	-0.042	-0.154	-0.098
60	3	0	3	-0.050	-0.203	-0.106
50	7	2	5	0.303	-0.763	-0.124
40	12	4	8	0.336	-0.472	-0.068
30	15	3	12	0.143	-0.347	-0.129
20	30	9	21	0.186	-0.300	-0.031
10	21	8	13	0.156	-0.113	-0.005
5	38	15	23	0.105	-0.098	-0.005
Total	131	41	90	0.336	-0.763	-0.049

Table 11. Least Squares Results for Unstable Contracts using Narrowing Interval Method to Define Stability

Stabilization Point	Freq.	Total (+)	Total (-)	Slope Max.	Slope Min.	Slope Mean
95	1	1	0	0.160	0.160	0.160
90	2	1	1	0.129	-0.046	0.041
80	1	0	1	-0.015	-0.015	-0.015
70	2	1	1	0.070	-0.088	-0.009
60	3	0	3	-0.066	-0.271	-0.200
50	6	3	3	0.212	-0.317	-0.085
40	3	0	3	-0.154	-0.280	-0.222
30	4	1	3	0.204	-0.167	-0.025
20	10	4	6	0.206	-0.121	-0.014
10	10	4	6	0.053	-0.052	-0.007
5	8	4	4	0.048	-0.091	-0.007
Total	50	19	31	0.212	-0.317	-0.039

The following observations are made from the tables above:

- The means of the slopes are negative for all but the 90 and 95 percent complete stabilization points in Tables 9 and 11. These positive slopes are due to the contract baseline being adjusted for the two contracts shown to have positive slopes. When the baseline is adjusted, the BAC is increased to reflect the current overrun. At the time when the baseline is adjusted, the $BCWP_{cum}$ is set to equal the $ACWP_{cum}$. Essentially, the CPI_{cum} is reset to 1.0 at that point in time, thus presenting the appearance of a positive trend. From Table 10, which excludes all of the unstable contracts, it is seen that the means of the slopes are negative for all percent complete stabilization points.
- From Table 9, it can be seen that the number of contracts having negative slopes was 121 compared to only 60 having positive slopes. Thus, there is a 67% chance that a contract's CPI_{cum} will decline as the contract progresses.

D. NARROWING INTERVAL METHOD

The results from the narrowing interval method are displayed in Table 12. For a contract to be declared stable for the percent complete point specified, all CPI_{cum} values must fall on or within the interval produced by subtracting .10 from the maximum CPI_{cum} value and adding .10 to the minimum CPI_{cum} value. The table reports the number of contracts analyzed, the number of those contracts that are declared stable, and the associated percentage of contracts declared stable.

Table 12. Summary of the Narrowing Interval Method CPI_{cum} Results

	Percent Complete					
	5%	10%	20%	30%	40%	50%
Number of Contracts	103	141	180	181	181	181
Number Stable	46	77	117	136	151	164
% Stable	45%	55%	65%	75%	83%	91%

In comparison to the range method which showed stability down to the 20% complete point, stability occurs at the 40% to 50% complete point using the narrowing interval method. This is due to the more stringent definition of stability, which is that the CPI_{cum} is within plus or minus .10 for all points within the specified interval. At the 30% complete point, only 75% of the contracts in this study were declared stable using the narrowing interval method compared to 96% using the range method.

E. CONFIDENCE INTERVAL FOR THE PROPORTION OF STABLE CONTRACTS USING THE NARROWING INTERVAL METHOD

The proportion of stable contracts was presented in the previous section. In this section, the 90%, 95%, and 99% confidence intervals for the proportion of stable contracts will be presented. Tables 13 through 15 show the calculated confidence intervals for the 90%, 95% and 99% confidence levels respectively. The tables list the number of contracts analyzed, the number of stable contracts, the proportion of stable contracts, the two-tail z critical value, and the calculated upper and lower limits.

Table 13. 90% Confidence Interval for the Proportion of Stable Contracts

	Percent Complete					
	5%	10%	20%	30%	40%	50%
Number of Contracts	103	141	180	181	181	181
Number Stable	46	77	117	136	151	164
Percent Stable	45%	55%	65%	75%	83%	91%
Z Critical Value	1.645	1.645	1.645	1.645	1.645	1.645
Upper Limit	0.528	0.614	0.706	0.800	0.875	0.936
Lower Limit	0.368	0.477	0.590	0.695	0.784	0.864

Table 14. 95% Confidence Interval for the Proportion of Stable Contracts

	Percent Complete					
	5%	10%	20%	30%	40%	50%
Number of Contracts	103	141	180	181	181	181
Number Stable	46	77	117	136	151	164
Percent Stable	45%	55%	65%	75%	83%	91%
Z Critical Value	1.960	1.960	1.960	1.960	1.960	1.960
Upper Limit	0.543	0.626	0.716	0.809	0.881	0.941
Lower Limit	0.354	0.464	0.578	0.684	0.773	0.855

Table 15. 99% Confidence Interval for the Proportion of Stable Contracts

	Percent Complete					
	5%	10%	20%	30%	40%	50%
Number of Contracts	103	141	180	181	181	181
Number Stable	46	77	117	136	151	164
Percent Stable	45%	55%	65%	75%	83%	91%
Z Critical Value	2.576	2.576	2.576	2.576	2.576	2.576
Upper Limit	0.572	0.65	0.735	0.824	0.893	0.948
Lower Limit	0.327	0.438	0.555	0.661	0.752	0.835

From Table 15, the lower limit for the 99% confidence interval at the 40% complete point is only 75%. Thus, it is only with reservation that it can be said that stability occurs at the 40% complete point. At the 50% complete point, the 99% confidence interval, which is from approximately 84% to 95%, provides a level of security that the CPI_{cum} has stabilized.

F. CATEGORICAL EVALUATION

The results of the categorical examination are presented in Tables 16 through 21. This examination looks at the relationship between CPI_{cum} stability and contract characteristics. The general characteristics are type, phase, time period, and stability of the baseline. The specific characteristics for type are: FFP and FFP combinations, FPIF, CPFF, and CPIF & CPAF. For phase and time period, the specific characteristics are: Development, LRIP, and Production; and Pre-A12, Transitional, and Post-A12 respectively. Lastly, stability of the baseline will be classified as stable or unstable. A total of 58 different combinations of contract groupings will be evaluated. Not all possible combinations are presented; combinations with fewer than eight contracts are omitted. The 58 combinations are listed as the first column of each table. The second column lists the number of contracts in the study with the specified characteristics. The remaining two columns report the number and percentage of contracts with the specified characteristics that have stable CPI_{cum} values for the completion point declared in the table title. A separate table is presented for the 5%, 10%, 20%, 30%, 40%, and 50% complete points.

Table 16. Contract Characteristics and Stability Relationship from the 5% Complete Point

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
FFP	10	7	70%
FPIF	62	27	44%
CPFF	11	3	27%
CPIF	15	7	47%
Dev	21	8	38%
LRIP	12	4	33%
Prod	64	31	48%
Pre	30	12	40%
Trans	29	15	52%
Post	44	19	43%
S	73	38	52%
U	30	8	27%
FPIF/Prod	51	23	45%
CPFF/Dev	9	2	22%
CPIF/Dev	8	4	50%
FPIF/Pre	15	5	33%
FPIF/Trans	25	12	48%
FPIF/Post	22	10	46%
CPFF/Pre	8	2	25%
CPIF/Post	10	3	30%
FFP/S	10	7	70%
FPIF/S	44	21	48%
FPIF/U	18	6	33%
Dev/Pre	12	5	42%
LRIP/Post	9	4	44%
Prod/Pre	15	7	47%
Prod/Trans	24	14	58%
Prod/Post	25	10	40%
Dev/S	13	7	54%
Dev/U	8	1	13%
LRIP/S	12	4	33%
Prod/S	44	25	57%
Prod/U	20	6	30%
Pre/S	22	11	50%
Pre/U	8	1	13%
Trans/S	21	11	52%
Trans/U	8	4	50%
Post/S	30	16	53%
Post/U	14	3	21%
FPIF/Prod/S	35	17	49%

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
FPIF/Prod/U	16	6	38%
FPIF/Pre/S	11	5	46%
FPIF/Trans/S	17	8	47%
FPIF/Trans/U	8	4	50%
FPIF/Post/S	16	8	50%
Prod/Pre/S	11	7	64%
Prod/Trans/S	17	10	59%
Prod/Post/S	16	8	50%
Prod/Post/U	9	2	22%

FFP	Firm Fixed Price and FFP Combinations
FPIF	Fixed Price Incentive Fee
CPFF	Cost Plus Fixed Fee
CPIF	Cost Plus Incentive Fee & Cost Plus Award Fee
Dev	Development
LRIP	Low Rate Initial Production
Prod	Production
Pre	Pre-A12
Trans	Transitional
Post	Post-A12
S	Stable Baseline
U	Unstable Baseline

Table 17. Contract Characteristics and Stability Relationship from the 10% Complete Point

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
FFP	15	14	93%
FPIF	81	42	52%
CPFF	16	6	38%
CPIF	23	10	44%
Dev	30	13	43%
LRIP	14	7	50%
Prod	86	51	59%
Pre	45	21	47%
Trans	38	22	58%
Post	58	34	59%
S	100	59	59%
U	41	18	44%
FFP/Prod	11	10	91%
FPIF/LRIP	8	3	38%
FPIF/Prod	66	36	55%
CPFF/Dev	12	3	25%
CPIF/Dev	12	6	50%
FFP/Post	8	8	100%
FPIF/Pre	22	8	36%
FPIF/Trans	33	19	58%
FPIF/Post	26	15	58%
CPFF/Pre	13	5	39%
CPIF/Post	17	6	35%
FFP/S	15	14	93%
FPIF/S	58	30	52%
FPIF/U	23	12	52%
CPFF/S	12	4	33%
CPIF/S	10	7	70%
Dev/Pre	17	8	47%
Dev/Post	10	5	50%
LRIP/Post	11	7	64%
Prod/Pre	24	12	50%
Prod/Trans	32	21	66%
Prod/Post	30	18	60%
Dev/S	18	9	50%
Dev/U	12	4	33%
LRIP/S	14	7	50%
Prod/S	61	39	64%
Prod/U	25	12	48%
Pre/S	36	17	47%

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
Pre/U	9	4	44%
Trans/S	25	15	60%
Trans/U	13	7	54%
Post/S	39	27	69%
Post/U	19	7	37%
FPIF/Prod/S	45	24	53%
FPIF/Prod/U	21	12	57%
FPIF/Pre/S	18	7	39%
FPIF/Trans/S	21	12	57%
FPIF/Trans/U	12	7	58%
FPIF/Post/S	19	11	58%
Prod/Pre/S	20	11	55%
Prod/Trans/S	21	14	67%
Prod/Trans/U	11	7	64%
Prod/Post/S	20	14	70%
Prod/Post/U	10	4	40%

FFP	Firm Fixed Price and FFP Combinations
FPIF	Fixed Price Incentive Fee
CPFF	Cost Plus Fixed Fee
CPIF	Cost Plus Incentive Fee & Cost Plus Award Fee
Dev	Development
LRIP	Low Rate Initial Production
Prod	Production
Pre	Pre-A12
Trans	Transitional
Post	Post-A12
S	Stable Baseline
U	Unstable Baseline

Table 18. Contract Characteristics and Stability Relationship from the 20% Complete Point

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
FFP	20	19	95%
FPIF	98	63	64%
CPFF	24	13	54%
CPIF	32	17	53%
Dev	41	24	59%
LRIP	16	10	63%
Prod	103	72	70%
Pre	67	43	64%
Trans	43	27	63%
Post	70	47	67%
S	130	89	69%
U	50	28	56%
FFP/Prod	13	13	100%
FPIF/LRIP	8	5	63%
FPIF/Prod	78	53	68%
CPFF/Dev	16	9	56%
CPIF/Dev	18	10	56%
FFP/Pre	9	8	89%
FFP/Post	8	8	100%
FPIF/Pre	32	18	56%
FPIF/Trans	36	23	64%
FPIF/Post	30	22	73%
CPFF/Pre	20	12	60%
CPIF/Post	25	12	48%
FFP/S	19	19	100%
FPIF/S	69	44	64%
FPIF/U	29	19	66%
CPFF/S	19	10	53%
CPIF/S	18	12	67%
Dev/Pre	22	16	73%
Dev/Post	15	8	53%
LRIP/Post	12	8	67%
Prod/Pre	35	23	66%
Prod/Trans	34	24	71%
Prod/Post	34	25	74%
Dev/S	28	18	64%
Dev/U	13	6	46%
LRIP/S	15	10	67%
Prod/S	74	53	72%
Prod/U	29	19	66%

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
Pre/S	55	37	67%
Pre/U	12	6	50%
Trans/S	27	18	67%
Trans/U	16	9	56%
Post/S	48	34	71%
Post/U	22	13	59%
FPIF/Prod/S	54	34	63%
FPIF/Prod/U	24	19	79%
FPIF/Pre/S	27	16	59%
FPIF/Trans/S	21	14	67%
FPIF/Trans/U	15	9	60%
FPIF/Post/S	21	14	67%
FPIF/Post/U	9	8	89%
Prod/Pre/S	30	21	70%
Prod/Trans/S	22	15	68%
Prod/Trans/U	12	9	75%
Prod/Post/S	22	17	77%
Prod/Post/U	12	8	67%

FFP	Firm Fixed Price and FFP Combinations
FPIF	Fixed Price Incentive Fee
CPFF	Cost Plus Fixed Fee
CPIF	Cost Plus Incentive Fee & Cost Plus Award Fee
Dev	Development
LRIP	Low Rate Initial Production
Prod	Production
Pre	Pre-A12
Trans	Transitional
Post	Post-A12
S	Stable Baseline
U	Unstable Baseline

Table 19. Contract Characteristics and Stability Relationship from the 30% Complete Point

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
FFP	20	19	95%
FPIF	99	73	74%
CPFF	24	17	71%
CPIF	32	21	66%
Dev	41	27	66%
LRIP	17	15	88%
Prod	103	80	78%
Pre	67	49	73%
Trans	43	29	67%
Post	71	58	82%
S	131	104	79%
U	50	32	64%
FFP/Prod	13	13	100%
FPIF/LRIP	9	9	100%
FPIF/Prod	78	58	74%
CPFF/Dev	16	11	69%
CPIF/Dev	18	11	61%
FFP/Pre	9	8	89%
FFP/Post	8	8	100%
FPIF/Pre	32	20	63%
FPIF/Trans	36	25	69%
FPIF/Post	31	28	90%
CPFF/Pre	20	16	80%
CPIF/Post	25	16	64%
FFP/S	19	19	100%
FPIF/S	70	52	74%
FPIF/U	29	21	72%
CPFF/S	19	14	74%
CPIF/S	18	14	78%
Dev/Pre	22	18	82%
Dev/Post	15	9	60%
LRIP/Post	13	12	92%
Prod/Pre	35	24	69%
Prod/Trans	34	26	77%
Prod/Post	34	30	88%
Dev/S	28	21	75%
Dev/U	13	6	46%
LRIP/S	16	15	94%
Prod/S	74	58	78%
Prod/U	29	22	76%

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
Pre/S	55	42	76%
Pre/U	12	7	58%
Trans/S	27	19	70%
Trans/U	16	10	63%
Post/S	49	43	88%
Post/U	22	15	68%
FPIF/Prod/S	54	38	70%
FPIF/Prod/U	24	20	83%
FPIF/Pre/S	27	17	63%
FPIF/Trans/S	21	15	71%
FPIF/Trans/U	15	10	67%
FPIF/Post/S	22	20	91%
FPIF/Post/U	9	8	89%
Prod/Pre/S	30	22	73%
Prod/Trans/S	22	16	73%
Prod/Trans/U	12	10	83%
Prod/Post/S	22	20	91%
Prod/Post/U	12	10	83%

FFP	Firm Fixed Price and FFP Combinations
FPIF	Fixed Price Incentive Fee
CPFF	Cost Plus Fixed Fee
CPIF	Cost Plus Incentive Fee & Cost Plus Award Fee
Dev	Development
LRIP	Low Rate Initial Production
Prod	Production
Pre	Pre-A12
Trans	Transitional
Post	Post-A12
S	Stable Baseline
U	Unstable Baseline

Table 20. Contract Characteristics and Stability Relationship from the 40% Complete Point

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
FFP	20	19	95%
FPIF	99	86	87%
CPFF	24	18	75%
CPIF	32	22	69%
Dev	41	28	68%
LRIP	17	15	88%
Prod	103	94	91%
Pre	67	56	84%
Trans	43	34	79%
Post	71	61	86%
S	131	116	89%
U	50	35	70%
FFP/Prod	13	13	100%
FPIF/LRIP	9	9	100%
FPIF/Prod	78	71	91%
CPFF/Dev	16	12	75%
CPIF/Dev	18	11	61%
FFP/Pre	9	8	89%
FFP/Post	8	8	100%
FPIF/Pre	32	26	81%
FPIF/Trans	36	30	83%
FPIF/Post	31	30	97%
CPFF/Pre	20	17	85%
CPIF/Post	25	17	68%
FFP/S	19	19	100%
FPIF/S	70	63	90%
FPIF/U	29	23	79%
CPFF/S	19	15	79%
CPIF/S	18	14	78%
Dev/Pre	22	19	86%
Dev/Post	15	9	60%
LRIP/Post	13	12	92%
Prod/Pre	35	30	86%
Prod/Trans	34	31	91%
Prod/Post	34	33	97%
Dev/S	28	22	79%
Dev/U	13	6	46%
LRIP/S	16	15	94%
Prod/S	74	69	93%
Prod/U	29	25	86%

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
Pre/S	55	49	89%
Pre/U	12	7	58%
Trans/S	27	22	81%
Trans/U	16	12	75%
Post/S	49	45	92%
Post/U	22	16	73%
FPIF/Prod/S	54	49	91%
FPIF/Prod/U	24	22	92%
FPIF/Pre/S	27	23	85%
FPIF/Trans/S	21	18	86%
FPIF/Trans/U	15	12	80%
FPIF/Post/S	22	22	100%
FPIF/Post/U	9	8	89%
Prod/Pre/S	30	28	93%
Prod/Trans/S	22	19	86%
Prod/Trans/U	12	12	100%
Prod/Post/S	22	22	100%
Prod/Post/U	12	11	92%

FFP	Firm Fixed Price and FFP Combinations
FPIF	Fixed Price Incentive Fee
CPFF	Cost Plus Fixed Fee
CPIF	Cost Plus Incentive Fee & Cost Plus Award Fee
Dev	Development
LRIP	Low Rate Initial Production
Prod	Production
Pre	Pre-A12
Trans	Transitional
Post	Post-A12
S	Stable Baseline
U	Unstable Baseline

Table 21. Contract Characteristics and Stability Relationship from the 50% Complete Point

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
FFP	20	19	95%
FPIF	99	90	91%
CPFF	24	22	92%
CPIF	32	27	84%
Dev	41	35	85%
LRIP	17	15	88%
Prod	103	98	95%
Pre	67	59	88%
Trans	43	39	91%
Post	71	66	93%
S	131	123	94%
U	50	41	82%
FFP/Prod	13	13	100%
FPIF/LRIP	9	9	100%
FPIF/Prod	78	74	95%
CPFF/Dev	16	14	88%
CPIF/Dev	18	16	89%
FFP/Pre	9	8	89%
FFP/Post	8	8	100%
FPIF/Pre	32	27	84%
FPIF/Trans	36	33	92%
FPIF/Post	31	30	97%
CPFF/Pre	20	19	95%
CPIF/Post	25	21	84%
FFP/S	19	19	100%
FPIF/S	70	66	94%
FPIF/U	29	24	83%
CPFF/S	19	17	90%
CPIF/S	18	16	89%
Dev/Pre	22	19	86%
Dev/Post	15	14	93%
LRIP/Post	13	12	92%
Prod/Pre	35	32	91%
Prod/Trans	34	33	97%
Prod/Post	34	33	97%
Dev/S	28	25	89%
Dev/U	13	10	77%
LRIP/S	16	15	94%
Prod/S	74	72	97%
Prod/U	29	26	90%

Characteristics	Number of Contracts	Number with Stable CPI_{cum}	Percentage with Stable CPI_{cum}
Pre/S	55	51	93%
Pre/U	12	8	67%
Trans/S	27	25	93%
Trans/U	16	14	88%
Post/S	49	47	96%
Post/U	22	19	86%
FPIF/Prod/S	54	52	96%
FPIF/Prod/U	24	22	92%
FPIF/Pre/S	27	24	89%
FPIF/Trans/S	21	20	95%
FPIF/Trans/U	15	13	87%
FPIF/Post/S	22	22	100%
FPIF/Post/U	9	8	89%
Prod/Pre/S	30	29	97%
Prod/Trans/S	22	21	96%
Prod/Trans/U	12	12	100%
Prod/Post/S	22	22	100%
Prod/Post/U	12	11	92%

FFP	Firm Fixed Price and FFP Combinations
FPIF	Fixed Price Incentive Fee
CPFF	Cost Plus Fixed Fee
CPIF	Cost Plus Incentive Fee & Cost Plus Award Fee
Dev	Development
LRIP	Low Rate Initial Production
Prod	Production
Pre	Pre-A12
Trans	Transitional
Post	Post-A12
S	Stable Baseline
U	Unstable Baseline

The study of the relationship between the CPI_{cum} stabilization points and the contract characteristics allows comparison among the different characteristics. Comparing the four types of contracts, FFP contracts have a higher percentage of stability than the other types. From Table

17, 93% of the FFP contracts were stable at the 10% complete point. For the remaining three types, FPIF and CPFF contracts have higher percentages of stability compared to CPIF & CPAF contracts from the 20% complete point onward. It should be noted that in general, fixed price contracts are more stable than incentive and award fee contracts. From Table 21, there were 20 FFP contracts and 24 CPFF contracts, of which, 19 and 22 were stable at the 50% complete point respectively. Combining these two types, 41 out of 44, or 93% of the fixed price contracts are stable at the 50% complete point. In comparison, there were 99 FPIF contracts and 32 CPIF contracts, of which, 90 and 27 were stable at the 50% complete point respectively. Combining these two types, 117 out of 131, or 89% of the incentive and award fee contracts are stable at the 50% complete point. As one person in OSD who is knowledgeable about this issue said:

> The categorical analysis fits intuitively. FPIF and FFP contracts are bid on programs or phases of the programs that contractors understand very well (less risk). New developments or ill-defined/poorly scoped programs (lots of risk) will be bid out as CPIF or CPAF. (LTC J. Thurman, personal communication, May 15, 2007)

Looking at the different phases examined in this study, contracts in the production phase had a higher percentage of stability at the 40% and 50% complete points relative to the other two. The LRIP contracts had a higher percentage of stability compared to development contracts from the 10% through the 50% complete point.

Contracts started after the A12 program cancellation had a higher percentage of stability relative to contracts

started before cancellation. Although the percentage is only slightly higher, this provides some evidence that the EVMS changes influenced by the A12 program cancellation may be having a positive impact.

Lastly, comparing contracts with stable baselines to those with unstable baselines, it is clear that contracts with stable baselines have a higher percentage of CPI_{cum} stability. For all complete points presented, contracts with stable baselines outperformed those with unstable baselines.

The relative findings just identified for type, phase, and baseline stability are in agreement with the findings presented by Heise (1991). The final chapter will provide a summary of all the findings presented in this chapter, as well as discuss the significance of the findings and recommend ideas for further research.

V. SUMMARY AND DISCUSSION

A. REVIEW OF THE HYPOTHESIS

The null hypothesis is that the CPI_{cum} stabilizes by the 50% complete point of a contract. The hypothesis was tested using both the range method and the narrowing interval method to determine CPI_{cum} stability. Both methods were applied on a sample of 181 contracts from 48 different programs taken from the DAMIR system.

B. CONCLUSION

The range method shows that the CPI_{cum} stabilized by the 50% complete point for 97% of the contracts included in this study. In fact, evidence was provided that the CPI_{cum} began to stabilize from the 10% to 20% complete points. In Table 7, the upper limits for the 99% confidence intervals at the 10% and 20% complete points were .153 and .117 respectively, which are both well within the .20 limit defined by the range method.

For the narrowing interval method, it was shown that the CPI_{cum} stabilized for 91% of the contracts included in this study by the 50% complete point. From Table 15, the lower limit of the 99% confidence interval at the 40% complete point was down to .752; thus stability will only be declared for contracts at the 50% complete point or greater.

C. DISCUSSION

Declaring the CPI_{cum} stable is not an end in itself. One of the many benefits of the CPI_{cum} is its value in estimating the cost at completion. The CPI_{cum} is only useful for this purpose if it can be declared stable. By the definition of CPI_{cum} stability, which is that CPI_{cum} will not vary by more than plus or minus .10, estimates made using a stable CPI_{cum} will not be more than 10% off the final cost of the contract. The definition just stated for CPI_{cum} stability is the one used in the narrowing interval method. Thus, the narrowing interval method provides a better measure of when a contract’s CPI_{cum} should be declared stable.

This study provides PMs and analysts with a solid foundation of CPI_{cum} stability percentages. This stability is observed in historical contracts at varying complete points and for various contract categories. With the results of this study, PMs and analysts should have more confidence in their cost at completion estimates.

The results can also be used to determine the probability that a contractor can recover from a cost overrun. In Chapter II, the To Complete Performance Index (TCPI) was defined as how well the contractor must perform throughout the remainder of the contract to finish within the planned budget. If the CPI_{cum} can be declared stable for a contract and the calculated TCPI is .10 or more above the current CPI_{cum} value, then by definition of CPI_{cum} stability, the contractor will not be able to complete the contract within the planned budget. Further, from the method of

least squares, it was shown that the CPI_{cum} for the average contract tends to decline rather than improve.

An example is provided below to demonstrate the utility of the results of this study. A FPIF contract, in the production phase, and with a stable baseline, has the following cost performance data:

Table 22. Cost Performance Data for Fictional Contract ($Millions)

$BCWP_{cum}$	$ACWP_{cum}$	BAC
100	110	250

Using equation (6), the percent complete is found by dividing the $BCWP_{cum}$ by the BAC, which is .4 [=100 / 250]. The table providing the contract characteristics and stability relationship from the 40% complete point is then checked to determine stability. From Table 20, the row labeled "FPIF/Prod/S" shows that 91% of the contracts reviewed in this study with the same characteristics as this fictional contract had stable CPI_{cum} values at the 40% complete point. It is thus assumed that the CPI_{cum} to be calculated for this contract may be declared stable. From equation (4), the CPI_{cum} is calculated by dividing the $BCWP_{cum}$ by the $ACWP_{cum}$, which is .909 [=100 / 110]. Equation (3) is now used to calculate the TCPI. The TCPI is found by dividing the BAC minus the $BCWP_{cum}$ by the BAC minus the $ACWP_{cum}$, which is 1.07 [=(250 – 100) / (250 – 110)]. From our definition of stability, the maximum that the CPI_{cum} can possibly improve to is 1.009 [=.909 + .10]. Thus, it is highly unlikely that the contractor will be able to finish within the planned BAC. Incorporating the results from the

method of least squares, the contractor will not only be unable to recover, it is highly likely that performance will decline throughout the remainder of the contract. At this point, the CPI_{cum} could further be used to determine an accurate estimate at completion.

D. RECOMMENDATIONS FOR FURTHER RESEARCH

This study looked at contracts which had cost performance data through the 85 percent complete point. It is recommended that historical data be analyzed for contracts which did not make it to the 85 percent complete point due to cancellation for poor cost performance. This would provide PMs and analysts with information on the early trends exhibited by contracts which are susceptible to cancellation.

Another area to investigate within the EVMS is the SPI. Many of the heuristics used to determine the EAC use a combination of the SPI_{cum} and the CPI_{cum}. The SPI_{cum} by definition (comparison of the cumulative budget for work actually performed with the cumulative budget for tasks scheduled) starts at 1.0 and returns to 1.0 at the completion of the contract. It is recommended that a historical analysis be conducted to determine trends in the SPI_{cum} in comparison to contract performance. For instance, what is the average time for schedule recovery when the SPI_{cum} is .90? For cancelled programs, what is the average SPI_{cum} at specified percent complete intervals? As the recommended study above suggests, this would provide PMs and analyst with trends displayed by contracts which have been terminated.

APPENDIX A: CONTRACTS INCLUDED IN STUDY

Table 23. Contracts Listed by Name, Phase, Type, Year, and Stability of the Baseline

Program/Contract	Type	Phase	Year	S/U
AIM-9X				
AIM-9X	CPIF/CPAF	Dev	1997-2003	S
AIM-9X	CPIF	Dev	1995-1996	S
AIM-9X	CPIF	Dev	1995-1996	S
AN/BSY-1				
TT/WLSOT Dev/Prod	FPIF		1988-1991	S
AN/SQQ-89				
EMSP S/W Conversion	CPAF		1993-1995	S
Shipboard Elect Subsys.	CPFF		1980-1983	S
Array Equipment	CPFF		1980-1983	S
AOE-6				
AOE 10	FPIF		1993-1997	S
AOE 8	FPIF		1991-1995	U
AOE 7	FPIF		1990-1994	U
ASPJ				
ASPJ Lot I Prod	FPIF	Prod	1989-1992	S
ASPJ Lot I Production	FPIF	Prod	1990-1992	S
C/MH-53E				
FY78 Buy 6 A/C	FPIF	Prod	1978-1982	S
FY80 Buy 15 A/C	FPIF	Prod	1981-1982	S
FY79 Buy 14 A/C	FPIF	Prod	1979-1982	U
CAPTOR (MK 60 MINE)				
Mine	FPIF		1981-1983	S
CG-47				
CG 69/71-73 Constr.	FPIF	Prod	1989-1993	S
CG-70 Constr.	FPIF	Prod	1988-1993	S
CG 66/8 Constr.	FPIF	Prod	1987-1992	S
Aegis Wpn Sys	FPIF	Prod	1988-1992	S
CG 67 Constr.	FPIF	Prod	1987-1992	S
CG 62/5 Constr.	FPIF	Prod	1987-1991	S
CG 60/1/3/4 Constr.	FPIF	Prod	1987-1991	U
CG-48 (Yorktown)	CPFF	Prod	1981-1984	S
CG-47 (Ticonderoga)	CPFF	Prod	1979-1983	U
CVN 68				
CVN 76 Constr.	FPIF	Prod	1995-2003	S
CVN-74/75 Constr.	FPIF	Prod	1988-1998	U
DDG 1000 (DD(X))				

DD(X) Phase III Dev	CPAF	Dev	2003-2006	S
DDG 51				
89/91/93… Constr.	FPIF	Prod	1998-2006	U
DDG90/92… Constr.	FPIF	Prod	1999-2006	U
Aegis Wpn Sys	FPIF	Prod	1999-2004	S
DDG 83/85/87 Constr.	FPIF	Prod	1996-2002	S
DDG 84/86/88 Constr.	FPIF	Prod	1996-2002	S
DDG 78,80,82 Constr.	FPIF	Prod	1994-2000	S
DDG 77,79,81 Constr.	FPIF	Prod	1995-2000	S
Aegis Wpn Sys	FPIF	Prod	1997-2000	S
DDG 73,75,76 Constr.	FPIF	Prod	1993-1998	U
DDG 74 Constr.	FPIF	Prod	1993-1998	S
Aegis Wpn Sys	FPIF	Prod	1994-1998	U
DDG 69,71 Constr.	FPIF	Prod	1992-1997	S
DDG 68,70,72 Constr.	FPIF	Prod	1992-1997	U
DDG 59,61,63… Constr.	FPIF	Prod	1991-1996	U
DDG 60,62,64… Constr.	FPIF	Prod	1990-1996	U
Aegis Wpn Sys	FPIF	Prod	1992-1995	S
DDG 55,57 Constr.	FPIF	Prod	1989-1994	U
DDG 54,56,58 Constr.	FPIF	Prod	1989-1994	U
DDG 53 Constr.	FPIF	Prod	1988-1993	U
Aegis Wpn Sys	FPIF	Prod	1990-1993	S
DDG 52 Constr.	FPIF	Prod	1988-1992	U
Aegis Wpn Sys	FPIF	Prod	1988-1992	S
DDG 51 Constr.	FPIF	Prod	1985-1991	U
Aegis Wpn Sys	FPIF	Prod	1986-1989	S
Combat Sys Engineering	CPFF	Dev	1982-1984	U
E-2C REPRODUCTION				
Msn Computer Upgrade	CPIF/CPAF		1995-2000	U
EFV				
Dem/Val	CPAF	Dev	1997-2001	U
F-14D				
FY80 Buy 30 A/C	FFP	Prod	1980-1982	S
Airframe Prod	FFP	Prod	1979-1981	S
Airframe	FFP		1977-1978	S
F/A-18A/B/C/D				
Airframe Dev	CPFF	Dev	1976-1982	U
Engine Dev	CPFF	Dev	1976-1981	U
F/A-18E/F				
Airframe LRIP 3	FPIF	LRIP	1999-2001	S
Engine LRIP 2/3	FPIF	LRIP	1999-2001	S
Engine EMD	CPAF/CPIF	Dev	1992-2000	U
Airframe EMD	CPAF/CPIF	Dev	1992-2000	S
Airframe LRIP 2	FPIF	LRIP	1998-2000	S
FDS				
SSIPS	CPIF	Dev	1992-1996	U

FDS UWS FSED	CPIF	Dev	1990-1995	U
FFG-7				
FY80 Buy (3 Ships)	FPIF	Prod	1980-1984	S
FY79 Buy (3 Ships)	FPIF	Prod	1980-1984	S
FY78 Buy (3 Ships)	FPIF	Prod	1979-1983	S
FY78 Buy (2 Ships)	FPIF	Prod	1978-1983	S
FY77 Buy (3 Ships)	FPIF	Prod	1979-1983	S
FY78 Buy (3 Ships)	FPIF	Prod	1979-1983	S
FY77 Buy (2 Ships)	FPIF	Prod	1977-1983	S
Five Ships	FPIF	Prod	1977-1981	S
Three Ships	FPIF	Prod	1977-1981	S
H-1 UPGRADES (4BW/4BN)				
H-1 Upgrade EMD Constr.	CPIF	Dev	1997-2005	U
HARM (NAVY)				
FORD LCS Dev Support	CPAF	Dev	1985-1988	S
LCS Dev Support(RAYTH)	CPAF	Dev	1985-1987	S
HARPOON				
Missile	FPIF	Prod	1976-1979	S
JSOW				
JSOW Unitary E&MD	CPFF	Dev	1996-2003	S
JSOW LRIP II	FPIF	LRIP	1998-2000	S
JTIDS (NAVY)				
Full Scale Dev	CPFF	Dev	1982-1985	S
LAMPS MKIII (SH-60B)				
Airframe Dev	CPFF	Dev	1978-1982	S
Sys Integration	CPFF	Dev	1977-1982	S
Engine Dev	CPFF	Dev	1978-1982	S
LCAC				
LCAC 61-72 Constr.	FFP	Prod	1991-1994	S
LCAC 49-51 Constr.	FPIF	Prod	1990-1993	S
LCAC 52-60 Constr.	FPIF	Prod	1990-1993	S
LCAC 37-48 Constr.	FPIF	Prod	1989-1993	S
LCAC 34-36 Constr.	FPIF	Prod	1989-1992	S
LCAC 15-23 Constr.	FPIF	Prod	1987-1991	S
LCAC 24-33 Constr.	FPIF	Prod	1987-1991	S
LHD 1				
LHD 6 Constr.	FPIF	Prod	1993-1998	S
LHD 5 Constr.	FPIF	Prod	1992-1997	U
LHD 4 Constr.	FPIF	Prod	1989-1994	U
LHD 3 Constr.	FPIF	Prod	1988-1993	U
LHD 2 Constr.	FPIF	Prod	1987-1992	U
LPD 17				
LPD 19	CPIF	Prod	2000-2005	U
LPD 18	CPIF	Prod	1999-2005	U
LPD 17	CPIF	Prod	1997-2005	U
MH-60R				

Dev (EMD I)	CPFF	Dev	1993-1999	U
Dev (ALFS)	CPIF	Dev	1992-1997	U
MHC 51				
MHC 61/62 (Option)	FFP	Prod	1993-1998	S
MHC 58,59,&60	FFP	Prod	1993-1997	S
MHC 56/57 (Option)	FPIF	Prod	1992-1996	U
MK 48 ADCAP				
L3 Test Equipment	FPIF		1988-1991	S
Follower Pilot (P1)	FPIF		1988-1991	U
MK 50 TORPEDO				
MK-50 Torpedo LRIP II	FPIF	LRIP	1990-1992	S
MK-50 Torpedo LRIP II	FPIF	LRIP	1990-1992	S
MK 50 Torpedo Qual…	FFP/FPIF	LRIP	1989-1991	U
MK 50 Torpedo LRIP I	FPIF	LRIP	1989-1991	S
MK 50 FSED	CPIF/FFP	Dev	1983-1990	S
PHALANX CIWS (MK-15)				
FY 87 GD Prod	FPIF	Prod	1988-1990	U
86 Prod	FPIF	Prod	1987-1989	S
PHOENIX (AIM-54C)				
Guidance Cntrl & AFRM	FPIF	Prod	1987-1992	S
SIDEWINDER (AIM-9L)(N)				
Guidance Dev	CPFF	Dev	1977-1980	S
Optical Tgt Detector	FPIF	Dev	1977-1979	S
SM 2 (BLKS I-IV)				
SM-2 Blk IV FY95-98…	CPAF/FPIF	LRIP	1996-2002	S
SM-2 Blk II GC&A	FPIF	Prod	1987-1990	S
MK-45 Mod 5 FY 87 Prod	FFP	Prod	1988-1989	S
SSDS				
WASP Minimissile	FPIF		1980-1983	S
SSGN				
Detail Design	CPIF	Dev	2003-2005	S
SSN 21 / AN/BSY-2				
SSN 22 Constr.	FPIF	Prod	1993-1998	U
SSN 21 Constr.	FPIF	Prod	1990-1997	U
AN/BSY-2 LP	FPIF		1989-1996	S
AN/BSY-2 FSD	FPIF	Dev	1988-1996	U
SSN 21 Detail Design	CPFF	Dev	1988-1995	S
NNS Contract Design	CPFF	Dev	1985-1987	S
SSN 688				
SSN 688 Attack Sub	FPIF	Prod	1987-1994	S
Flight X Ships	FPIF	Prod	1986-1993	U
SSN 700-710	FPIF	Prod	1974-1983	S
SSN 774 (VIRGINIA CLASS)				
SSN775 Constr.	CPIF	Prod	1999-2006	U
IPPD96 Contract	CPFF/CPIF		1996-2004	S
NSSN C31 Prime Contract	CPAF		1996-2000	U

STRATEGIC SEALIFT				
New Constr.	FPIF	Prod	1994-2001	S
New Constr.	FFP	Prod	1994-2001	S
Class Standard Equip.	FFP/FPAF	Prod	1993-2000	S
Conversion	FPIF		1993-1997	U
T-45TS				
Cockpit 21	CPIF	Dev	1993-1996	S
T-AKE				
New Constr., T-AKE 3	FPIF	Prod	2003-2006	S
New Constr., T-AKE 1	FPIF	Prod	2003-2005	S
TOMAHAWK				
FY81 CWCS Prod	CPFF	Prod	1982-1984	S
FY82 Cruise Engine	FPIF	Prod	1982-1984	S
SLCM/GLCM CWCS	CPFF	Prod	1980-1983	S
TRIDENT II MISSILE				
Missile Follow-on Prod	CPIF/FFP	Prod	1995-1997	S
Missile Follow-on Prod	CPIF/FFP	Prod	1994-1997	S
Missile Follow-on Prod	CPIF/FFP	Prod	1992-1996	S
Missile Follow-on Prod	CPIF/FFP	Prod	1991-1994	S
Guidance Piece Prod	FPIF	Prod	1992-1993	S
Missile Follow-on Prod	CPIF/FFP	Prod	1990-1993	S
Missile Follow-on Prod	CPIF	Prod	1989-1992	S
Missile Follow-on Prod	CPIF	Prod	1988-1991	S
Navigation Op. Sys	CPIF/FPIF	Dev	1984-1990	U
Missile Op. Sys	CPIF/FFP	Dev	1983-1990	S
Missile Op. Sys P	CPIF/FFP	Dev	1987-1990	S
Test Instr. Op. Sys	CPIF	Dev	1984-1990	U
Launcher Op. Sys	CPIF/FFP	Dev	1983-1989	S
Fire Control Op. Sys	CPIF	Dev	1984-1989	S
Guidance Sys Dev	CPFF	Dev	1983-1988	S
TRIDENT II SUB				
Submarine Grp VII Ships	FPIF	Prod	1988-1996	S
Submarine Grp VI Ships	FPIF	Prod	1987-1993	S
Submarine Grp V Ships	FPIF	Prod	1986-1992	S
Submarine Grp IV Ships	FPIF	Prod	1982-1990	S
TRIDENT SUB				
FY79 Missile Prod	CPFF	Prod	1980-1981	S
Missile Prod (C-4)	CPFF	Prod	1978-1981	S
V-22				
FY04 LRIP Lot 8 Airframe	FPIF/CPIF	LRIP	2003-2006	S
FY05 LRIP Lot 9 Airframe	FFP/FPIF	LRIP	2005-2006	S
EMD Airframe	CPAF		1993-2006	U
FY03 LRIP Lot 7 Airframe	FPIF	LRIP	2003-2005	S
FY00 LRIP 4 Airframe	FPIF	LRIP	2000-2003	S
FY99 LRIP 3 Airframe	CPIF	LRIP	1998-2003	S
CV-22 FFS#1 & NEWID	CPIF		2000-2003	S

MV-FFS#2	CPIF		2001-2003	S
MV-22 LRIP SIM.FFS/FTD	CPIF	LRIP	1998-2002	S
FY98 LRIP 2 (Airframe)	CPIF/CPFF	LRIP	1997-2002	S
FY97 LRIP 1 (Airframe)	CPIF/CPFF	LRIP	1996-2002	S
EMD (Engine)	CPIF	Dev	1993-1996	S
Tech Effort	CPFF	Dev	1991-1996	S
Prelim Design Stage I	CPFF	Dev	1983-1986	S
Prelim Design Stage II	CPFF	Dev	1984-1985	S

APPENDIX B: RESULTS OF RANGE METHOD

Table 24. Range From Given Percent Completion Point to Final CPR Entry

Program/Contract	Percent Complete 5%	10%	20%	30%	40%	50%
AIM-9X						
AIM-9X		0.08	0.05	0.04	0.03	0.03
AIM-9X			0.22	0.16	0.14	0.09
AIM-9X			0.12	0.1	0.09	0.07
AN/BSY-1						
TT/WLSOT Dev/Prod			0.34	0.34	0.24	0.24
AN/SQQ-89						
EMSP S/W Conversion			0.05	0.03	0.03	0.02
Shipboard Elec Subsys			0.16	0.08	0.05	0.03
Array Equipment			0.13	0.11	0.11	0.08
AOE-6						
AOE 10	0.09	0.09	0.09	0.09	0.09	0.09
AOE 8			0.2	0.2	0.19	0.09
AOE 7			0.3	0.3	0.3	0.3
ASPJ						
ASPJ Lot I Prod	0.71	0.42	0.19	0.11	0.09	0.08
ASPJ Lot I Production	1.05	0.51	0.35	0.15	0.12	0.05
C/MH-53E						
FY78 Buy 6 A/C	0.4	0.27	0.1	0.09	0.09	0.07
FY80 Buy 15 A/C		0.13	0.08	0.05	0.03	0.02
FY79 Buy 14 A/C	0.28	0.28	0.28	0.18	0.14	0.14
CAPTOR (MK 60 MINE)						
Mine		0.06	0.05	0.05	0.05	0.05
CG-47						
CG 69/71-73 Constr.	0.13	0.13	0.13	0.13	0.13	0.13
CG-70 Constr.	0.08	0.08	0.06	0.05	0.05	0.05
CG 66/8 Constr.	0.11	0.11	0.11	0.11	0.07	0.07
Aegis Wpn Sys		0.06	0.06	0.06	0.06	0.06
CG 67 Constr.	0.1	0.1	0.08	0.08	0.08	0.07
CG 62/5 Constr.			0.09	0.04	0.04	0.04
CG 60/1/3/4 Constr.			0.04	0.03	0.03	0.02
CG-48 (Yorktown)		0.05	0.04	0.04	0.02	0.02
CG-47 (Ticonderoga)	0.52	0.33	0.16	0.16	0.13	0.1

CVN 68						
CVN 76 Constr.	0.13	0.12	0.09	0.09	0.09	0.07
CVN-74/75 Constr.	0.26	0.06	0.06	0.06	0.06	0.04
DDG 1000 (DD(X))						
DD(X) Phase III Dev	0.04	0.04	0.04	0.04	0.03	0.02
DDG 51						
89/91/93… Constr.	0.09	0.09	0.09	0.09	0.06	0.05
DDG90/92… Constr.	0.12	0.12	0.08	0.06	0.06	0.06
Aegis Wpn Sys	0.13	0.04	0.04	0.02	0.02	0.02
DDG 83/85/87 Constr.	0.23	0.19	0.14	0.1	0.1	0.1
DDG 84/86/88 Constr.	0.1	0.1	0.1	0.1	0.1	0.09
DDG 78,80,82 Constr.	0.14	0.09	0.09	0.04	0.04	0.02
DDG 77,79,81 Constr.		0.12	0.12	0.12	0.1	0.08
Aegis Wpn Sys	0.09	0.09	0.08	0.06	0.06	0.04
DDG 73,75,76 Constr.	0.27	0.27	0.03	0.03	0.01	0.01
DDG 74 Constr.	0.06	0.06	0.06	0.06	0.02	0.02
Aegis Wpn Sys		0.04	0.02	0.02	0.02	0.02
DDG 69,71 Constr.	0.13	0.12	0.11	0.1	0.07	0.07
DDG 68,70,72 Constr.	0.05	0.05	0.05	0.05	0.04	0.02
DDG 59,61,63… Constr.	0.25	0.12	0.12	0.08	0.06	0.06
DDG 60,62,64… Constr.	0.06	0.05	0.04	0.04	0.04	0.01
Aegis Wpn Sys	0.23	0.21	0.09	0.07	0.05	0.02
DDG 55,57 Constr.	0.07	0.07	0.07	0.07	0.07	0.07
DDG 54,56,58 Constr.	0.19	0.15	0.1	0.1	0.1	0.1
DDG 53 Constr.		0.19	0.17	0.14	0.1	0.08
Aegis Wpn Sys	0.09	0.09	0.09	0.09	0.09	0.09
DDG 52 Constr.		0.21	0.21	0.17	0.09	0.05
Aegis Wpn Sys		0.06	0.06	0.06	0.06	0.06
DDG 51 Constr.	0.21	0.19	0.15	0.15	0.11	0.11
Aegis Wpn Sys			0.04	0.02	0.02	0.01
Combat Sys Eng.			0.09	0.08	0.08	0.08
E-2C REPRODUCTION						
Msn Computer Upgrade		0.14	0.1	0.1	0.1	0.1
EFV						
Dem/Val		0.08	0.08	0.07	0.07	0.06
F-14D						

FY80 Buy 30 A/C			0.05	0.05	0.05	0.04
Airframe Prod		0.02	0.01	0.01	0.01	0.01
Airframe			0.03	0.01	0.01	0.01
F/A-18A/B/C/D						
Airframe Dev	0.15	0.09	0.09	0.09	0.09	0.04
Engine Dev	0.05	0.05	0.05	0.05	0.05	0.05
F/A-18E/F						
Airframe LRIP 3	0.06	0.05	0.04	0.03	0.03	0.03
Engine LRIP 2/3	0.09	0.05	0.03	0.03	0.03	0.03
Engine EMD	0.15	0.13	0.1	0.07	0.07	0.06
Airframe EMD	0.07	0.07	0.02	0.02	0.02	0.02
Airframe LRIP 2				0.04	0.04	0.04
FDS						
SSIPS		0.13	0.13	0.13	0.13	0.12
FDS UWS FSED		0.23	0.23	0.23	0.17	0.13
FFG-7						
FY80 Buy (3 Ships)			0.19	0.19	0.19	0.09
FY79 Buy (3 Ships)		0.2	0.2	0.12	0.1	0.1
FY78 Buy (3 Ships)			0.15	0.12	0.11	0.04
FY78 Buy (2 Ships)			0.18	0.16	0.08	0.07
FY77 Buy (3 Ships)	0.19	0.19	0.15	0.13	0.04	0.02
FY78 Buy (3 Ships)	0.88	0.71	0.09	0.05	0.05	0.03
FY77 Buy (2 Ships)			0.16	0.16	0.09	0.03
Five Ships		0.06	0.06	0.06	0.06	0.06
Three Ships	0.09	0.09	0.05	0.05	0.05	0.03
H-1 UPGRADES (4BW/4BN)						
H1 Upgrade EMD Constr	0.27	0.14	0.14	0.14	0.14	0.04
HARM (NAVY)						
FORD LCS Dev Support	0.06	0.06	0.06	0.06	0.06	0.06
LCS Dev Support	0.02	0.02	0.02	0.02	0.02	0.01
HARPOON						
Missile	0.15	0.15	0.04	0.04	0.04	0.04
JSOW						
JSOW Unitary E&MD	0.08	0.08	0.08	0.08	0.08	0.08
JSOW LRIP II	0.13	0.13	0.13	0.08	0.07	0.07
JTIDS (NAVY)						
Full Scale Dev	0.3	0.26	0.2	0.18	0.17	0.17
LAMPS MKIII (SH-60B)						
Airframe Dev		0.22	0.15	0.08	0.03	0.02
Sys Integration	0.15	0.15	0.09	0.08	0.05	0.04
Engine Dev		0.2	0.16	0.07	0.06	0.04
LCAC						
LCAC 61-72 Constr.	0.1	0.06	0.06	0.05	0.05	0.05
LCAC 49-51 Constr.	0.21	0.18	0.18	0.17	0.13	0.09

LCAC 52-60 Constr.	0.09	0.08	0.08	0.08	0.05	0.02
LCAC 37-48 Constr.	0.09	0.07	0.07	0.07	0.07	0.06
LCAC 34-36 Constr.	0.75	0.45	0.11	0.1	0.1	0.1
LCAC 15-23 Constr.	0.09	0.09	0.09	0.08	0.07	0.06
LCAC 24-33 Constr.	0.06	0.06	0.05	0.05	0.05	0.05
LHD 1						
LHD 6 Constr.	0.17	0.17	0.16	0.11	0.08	0.07
LHD 5 Constr.	0.26	0.25	0.08	0.07	0.05	0.05
LHD 4 Constr.	0.09	0.09	0.09	0.09	0.09	0.09
LHD 3 Constr.		0.09	0.04	0.04	0.04	0.04
LHD 2 Constr.	0.08	0.08	0.08	0.08	0.07	0.07
LPD 17						
LPD 19	0.13	0.13	0.13	0.09	0.09	0.09
LPD 18	0.15	0.15	0.15	0.14	0.1	0.1
LPD 17	0.31	0.31	0.31	0.31	0.31	0.31
MH-60R						
Dev (EMD I)	0.13	0.13	0.13	0.13	0.07	0.03
Dev (ALFS)	0.19	0.19	0.19	0.16	0.12	0.08
MHC 51						
MHC 61/62 (Option)		0.1	0.1	0.1	0.1	0.1
MHC 58,59,&60		0.08	0.08	0.08	0.08	0.08
MHC 56/57 (Option)			0.1	0.1	0.1	0.1
MK 48 ADCAP						
L3 Test Equipment	0.12	0.11	0.07	0.07	0.07	0.04
Follower Pilot (P1)	0.18	0.18	0.18	0.06	0.06	0.06
MK 50 TORPEDO						
MK-50 Torpedo LRIP II	0.18	0.18	0.08	0.08	0.04	0.02
MK-50 Torpedo LRIP II	0.17	0.17	0.08	0.07	0.04	0.02
MK 50 Torpedo Qual…			0.19	0.18	0.14	0.14
MK 50 Torpedo LRIP I	0.29	0.19	0.13	0.08	0.04	0.04
MK 50 FSED	0.1	0.09	0.09	0.09	0.09	0.09
PHALANX CIWS (MK-15)						
FY 87 GD Prod	0.18	0.08	0.07	0.07	0.07	0.07
86 Prod	0.1	0.1	0.09	0.09	0.09	0.04
PHOENIX (AIM-54C)						
Guidance Cntrl & AFRM	0.22	0.15	0.14	0.13	0.1	0.1
SIDEWINDER (AIM-9L)(N)						
Guidance Dev		0.16	0.1	0.1	0.04	0.03
Optical Tgt Detector		0.15	0.15	0.14	0.14	0.14
SM 2 (BLKS I-IV)						
SM-2 Blk IV FY95-	0.14	0.12	0.11	0.1	0.1	0.1

98…						
SM-2 Blk II GC&A		0.31	0.29	0.24	0.23	0.22
MK45 Mod 5 FY 87 Prod		0.11	0.09	0.09	0.09	0.09
SSDS						
WASP Minimissile			0.1	0.08	0.05	0.04
SSGN						
Detail Design			0.04	0.02	0.01	0.01
SSN 21 / AN/BSY-2						
SSN 22 Constr.	0.17	0.07	0.05	0.05	0.05	0.04
SSN 21 Constr.			0.07	0.05	0.05	0.05
AN/BSY-2 LP	0.09	0.09	0.09	0.09	0.09	0.08
AN/BSY-2 FSD	0.16	0.16	0.13	0.13	0.13	0.13
SSN 21 Detail Design			0.18	0.18	0.18	0.18
NNS Contract Design			0	0	0	0
SSN 688						
SSN 688 Attack Sub		0.17	0.13	0.12	0.09	0.07
Flight X Ships		0.1	0.1	0.1	0.1	0.02
SSN 700-710		0.27	0.27	0.16	0.06	0.03
SSN 774 (VIRGINIA CLASS)						
SSN775 Constr.			0.14	0.1	0.09	0.07
IPPD96 Contract	0.12	0.08	0.06	0.05	0.04	0.04
NSSN C31 Contract	0.09	0.09	0.09	0.09	0.09	0.09
STRATEGIC SEALIFT						
New Constr.	0.08	0.08	0.04	0.04	0.04	0.03
New Constr.	0.16	0.1	0.1	0.1	0.1	0.1
Class Standard Equip.	0.08	0.08	0.06	0.02	0.02	0.02
Conversion			0.19	0.19	0.17	0.15
T-45TS						
Cockpit 21			0.08	0.08	0.08	0.08
T-AKE						
New Constr., T-AKE 3	0.08	0.08	0.08	0.08	0.07	0.07
New Constr., T-AKE 1			0.13	0.08	0.04	0.03
TOMAHAWK						
FY81 CWCS Prod			0.15	0.1	0.1	0.1
FY82 Cruise Engine			0.07	0.04	0.04	0.03
SLCM/GLCM CWCS			0.08	0.08	0.05	0.03
TRIDENT II MISSILE						
Missile F/O Prod	0.05	0.05	0.05	0.04	0.03	0.02
Missile F/O Prod		0.04	0.04	0.03	0.03	0.02
Missile F/O Prod	0.06	0.06	0.06	0.05	0.04	0.04

Missile F/O Prod	0.04	0.04	0.02	0.02	0.01	0.01
Guidance Piece Prod			0.01	0.01	0.01	0.01
Missile F/O Prod			0.04	0.02	0.02	0.02
Missile F/O Prod	0.1	0.1	0.1	0.04	0.04	0.04
Missile F/O Prod	0.08	0.08	0.05	0.04	0.04	0.02
Navigation Op. Sys		0.09	0.04	0.03	0.03	0.03
Missile Op. Sys	0.09	0.08	0.07	0.06	0.03	0.02
Missile Op. Sys P			0.06	0.05	0.03	0.03
Test Instr. Op. Sys	0.39	0.19	0.19	0.19	0.19	0.17
Launcher Op. Sys	0.14	0.08	0.08	0.08	0.04	0.04
Fire Control Op. Sys			0.09	0.07	0.04	0.04
Guidance Sys Dev	0.16	0.16	0.06	0.05	0.02	0.02
TRIDENT II SUB						
Sub. Grp VII Ships	0.08	0.08	0.08	0.07	0.07	0.05
Sub. Grp VI Ships	0.13	0.08	0.08	0.05	0.05	0.04
Sub. Grp V Ships		0.08	0.08	0.08	0.08	0.07
Sub. Grp IV Ships	0.1	0.08	0.07	0.05	0.05	0.05
TRIDENT SUB						
FY79 Missile Prod		0.04	0.04	0.03	0.03	0.03
Missile Prod (C-4)	0.08	0.08	0.08	0.06	0.05	0.04
V-22						
FY04 LRIP Lot 8 A/F	0.25	0.06	0.05	0.04	0.03	0.03
FY05 LRIP Lot 9 A/F	0.24	0.06	0.06	0.06	0.04	0.01
EMD Airframe		0.05	0.05	0.05	0.04	0.02
FY03 LRIP Lot 7 A/F		0.11	0.11	0.07	0.06	0.04
FY00 LRIP 4 Airframe		0.1	0.04	0.04	0.04	0.04
FY99 LRIP 3 Airframe			0.03	0.03	0.03	0.03
CV-22 FFS#1 & NEWID		0.22	0.22	0.22	0.22	0.22
MV-FFS#2		0.31	0.22	0.04	0.03	0.02
MV-22 LRIP SIM/FTD	0.36	0.29	0.29	0.29	0.29	0.29
FY98 LRIP 2 (A/F)	0.06	0.06	0.06	0.06	0.06	0.06
FY97 LRIP 1 (A/F)	0.09	0.09	0.03	0.02	0.02	0.02
EMD (Engine)			0.17	0.15	0.11	0.08
Tech Effort	0.13	0.13	0.13	0.13	0.13	0.07
Prelim Dsgn Stage I	0.14	0.14	0.14	0.1	0.07	0.04
Prelim Dsgn Stage II			0.01	0.01	0.01	0.01

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